U.S. Shipbuilding Accuracy Phase

U.S. DEPARTMENT OF TRANSPORTATION

Maritime Administration

in cooperation with

Todd Pacific Shipyards Corporation

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FOREWORD

U. S. *Shipbuilding Accuracy Phase I* is the first statistical representation of pertinent data collected from those U.S. shipyards which are sufficiently advanced in their employment of statistical analysis of accuracy variations for structural work. Their objective is to constantly improve quality and productivity.

The efforts involve major commitments to, at first, formally organize work along product lines and to record thousands of dimensions to create a data base which confirms that work processes are in control, and thereafter to verify by random sampling that work processes remain in control. So established, statistical accuracy control is another production "tool'" used by workers and their immediate supervision.

The greater knowledge of how work processes perform, made available by statistical control methods, identifies problems so as to efficiently direct remedial and developmental efforts. Per advice publIshed in 1967 by The Society of Naval Architects of Japan, statistical control "epoch makingly" improved quality, laid the foundation of modem ship construction methods, and made it possible to extensively develop automated and specialized weldlng.

Secondly, statistical analysis of accuracy variations during part fabrication and assembly facilitates use of variation-merging equations for predicting, with great assurance, final end-product accuracy. This aspect is of particular importance for special vessels where abilities to withstand thermal shock, high-impact shock, and/or deep submergence is directly related to accuracies achieved without forced fitting during construction. The U.S. Navy has already included in-process statistical controI requirements in the specifications for building DDG-51 Class destroyers.

Also, traditional pre-contract negotiations between an owner and a shipbuilder only define a vessel's performance, material requirements, and fictional requirements of machinery systems and equipment. These establish the basis for material costs but not labor costs, which are addressed by the most effective shipbuilders and knowledgeable owners by also negotiating technical matters concerning how the ship is going to be built and *what quality and workmanship is assured by the shipyard.*

This publication informs parties concerned of analytically derived tolerance limits so far obtained from data which describes work performing normally, i.e., data obtained from work processes in statistical control. Shipyard managers who are contributing especially benefit, as their data influences in their favor what is described as normal for the industry. Mutual agreement by owners and shipyard managers to employ the tolerances suggested herein should contribute to reducing costly inspection hassles and rework.

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K.D. Franz, Manager, ABSTECH, Portland, Oregon, served as the Project Researcher and principal author. ABSTECH, Paramus, New Jersey, was represented by E.J. Stanford who assisted as an Associate Researcher and E.T. Reilly, Manager of Marine Operations, who provided direction and support.

Special appreciation is expressed to the shipbuilders who have established statistical control systems and willingly contributed their records of accuracy variations that are used herein. As confidentiality was assured, specific acknowledgements are omitted.

Appreciation is also expressed to B.A. Dill and L.A. Willets of Todd's Los Angeles Division and to T.W. Lamoureaux and C.K. Kiyonaga of Todd's Naval Technology Division, who furnished essential administrative support.

This publication is an end product of one of the many projects managed and cost shared by Todd for the National Shipbuilding Research Program. The Program is a cooperative effort by the Maritime Administration's Office of Advanced Ship Development, the U.S. Navy, and the U.S. shipbuilding industry. The objective, described by Panel SP-2 of the Ship Production Committee of the Society of Naval Architects and Marine Engineers, is to improve productivity.

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1.0 INTRODUCTION

1.1 GENERAL

Work began on *U.S. Shipbuilding Accuracy Phase I* in February 1985. The first phase addresses accuracies normally achieved when manufacturing commonly used structural details for the midbody of the ship. Shipyards were contacted and asked to provide in-house data collected from their controlled manufacturing processes. Data subsequently received was statistically combined. Standard Ranges and Tolerance Limits of control dimensions are set forth per the accuracy table of Section 3.2. The data represents a mix of U.S. shipyards doing both commercial and naval construction.

1.2 DOCUMENT USES

The following represent some of the advantages this document will provide the U.S. shipbuilders:

- Establish an industry base representing accuracies normally achieved in U.S. shipbuilding
- Develop criteria, based on actual industry performance, to identify and define what constitutes rework
- Provide shipyards a means to judge in-house process quality
- Provide a normal performance level of accuracy to be used in contract preparations and negotiations
- Provide general criteria for inspection
- Provide a means to monitor industry accuracy performance through periodic accuracy document updates
- Identify extraordinary contract accuracy requirements during bid preparation for appropriate cost considerations

2.0 APPROACH TO DOCUMENT PREPARATION

2.1 REFERENCES

The following National Shipbuilding Research Program (NSRP) publications were used as a basis for process manufacturing and accuracy control terminology

- *Product Work Breakdown Structure,* Revised December 1982
- *Process Analysis Via Accuracy Control,* Revised August 1985

2.2 DEFINITIONS

Definitions for standard ranges and tolerance limits are the same as found in the *Japanese Shipbuilding Quality Standard (Hull Part) -1979,* published by the Research Committee on Steel Shipbuilding, The Society of Naval Architects of Japan. For a process with a normal statistical distribution, *standard range* is that part of the process variation which falls within two standard deviations, representing 95.44% probability of occurrence. *Tolerance limit is* that part of the process variation which falls within three standard deviations, representing 99.73% probability of occurrence. Standard range is proposed for use in variation merging equations. Tolerance limit is proposed as criteria for rework.

3.0 STANDARD RANGES AND TOLERANCE LIMITS

3.1 COMMENTS ON DATA

Standard ranges and tolerance limits for those items marked with an asterisk are taken from the *Japanese Shipbuilding Quality Standard* (JSQS) and are to be considered a “temporary value” pending additional submittals of data.

To date, ABSTECH has received statistically valid data from three U.S. shipyards. The data is limited to flat block assembly production and structural shapes. Shipyards which have data from a controlled manufacturing process should submit their data to ABSTECH for consideration in future updates of this document. Data submitted should include the following information as a minimum

- Work process description
- Description of methods used to collect data
- Methods used to check “process control”
- Dates of samples
- Size of samples
- Physical description of product being sampled
- Data average, variance, and standard deviation

Graphical presentation of data using a histogram or frequency distribution is suggested to organize data for evaluation.

‘Why is it that productivity increases as quality improves?”

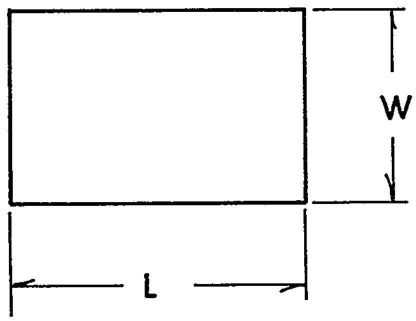
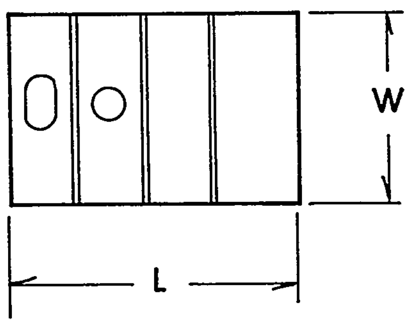
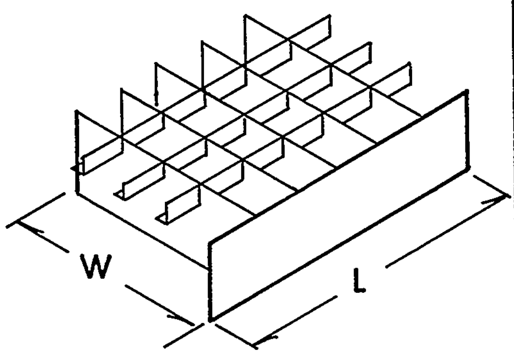
“Less Rework.”

Dr. W. Edwards Deming

3.2 STANDARD RANGES AND TOLERANCE LIMITS

ACCURACY PHASE I

Dimensions in Inches

Item	Manufacturing Level	Dimension	Standard Range	Tolerance Limit
FLAT PLATE	PART FABRICATION 	Length - L	± .092	± .138
		Width - W	± .086	± .129
		Diagonals	± .137	± .205
	SUB-BLOCK ASSEMBLY 	Length - L	± .198	± .297
		Width - W	± .220	± .332
		Diagonals	± .334	± .501
	SEMI-BLOCK AND BLOCK ASSEMBLY 	Length - L	± .268	± .402
		Width - W	± .495	± .743
		Diagonals *	± .157	± .315

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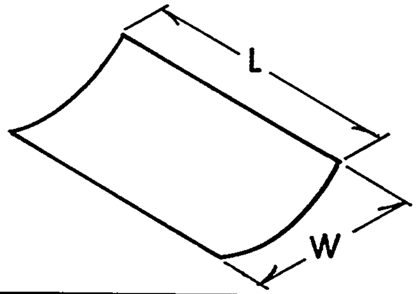
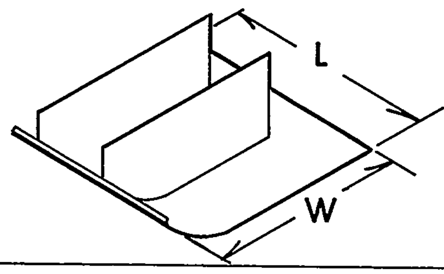
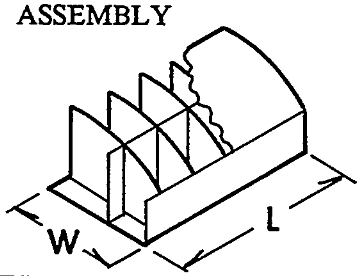
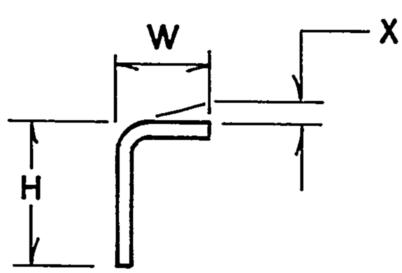
ACCURACY PHASE 1

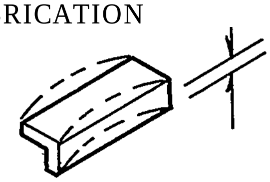
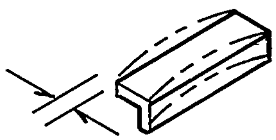
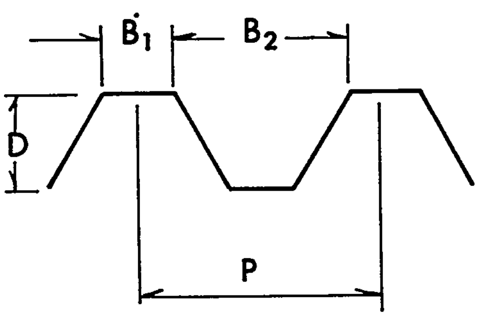
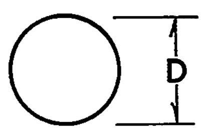
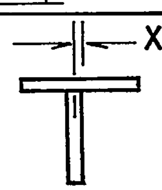
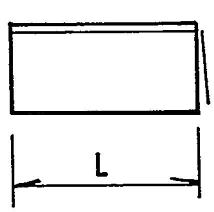
Dimensions in Inches

Item	Manufacturing Level	Dimension	Standard Range	Tolerance Limit
CURVED PLATE	PART FABRICATION 	Length - L *	± .098	± .197
		Width - W *	± .098	± .197
	SUB-BLOCK ASSEMBLY 	Length - L *	± .157	± .236
		Width - W *	± .157	± .236
	SEMI-BLOCK AND BLOCK ASSEMBLY 	Length - L *	± .157	± .236
		Width - W *	± .157	± .236
FLANGED PLATE	PART FABRICATION 	Flange Width - W *	± .118	± .197
		Section Height - H *	± .079	± .118
		Accuracy of Bend - X *	± .098 per 3.9 inches	± .177 per 3.9 inches

* See comment on rage 3.

ACCURACY PHASE I

Dimensions in Inches

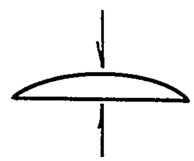
Item	Manufacturing Level	Dimension	Standard Range	Tolerance Limit
FLANGED PLATE (cont.)	PART FABRICATION 	Curvature in Plane of Flange *	± .394 per 33 feet	± .984 per 33 feet
		Curvature in Plane of Web *	± .394 per 33 feet	± .984 per 33 feet
CORRUGATED LATE	PART FABRICATION 	Depth of Corrugation	± .118	± .236
		Width of Corrugation B *	B_1: ±. 118 B2: ±.118	B1:±..236 B_2: ± 5.236
		Pitch of Corrugation P *	± .098	± .197
ROLLED PLATE	PART FABRICATION 	Diameter - D *	± .197	± .295
BUILT-UP PLATE SECTION	PART FABRICATION 	Face Plate Distortion - x *	± .059	± .118
STRUCTURAL SHAPES	PART FABRICATION 	Deviation of Fitted Length - L	± .131	± .196
		Squareness of Endcut	± .102	± .153

See Comment on Page 3.

3.2.4

ACCURACY PHASE 1

Dimensions in Inches

Item	Manufacturing Level	Dimension	Standard Range	Tolerance Limit
MARKING	CUTTING AND FITTING LINES FOR GENERAL HULL MEMBERS	Size and Shape	± .079	± .118
		Corner Angle *	± .059 per 39 inches	± .079 per 39 inches
		Curvature * 	± .039	± .059
		Member Location *	± .079	± .118
		Block Marking *	± .098	± .138

See comment on page 3.